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Filling the Airpower Vacuum

by

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USAWC STRATEGY RESEARCH PROJECT

Filling the Airpower Vacuum

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Abstract

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The Air Force faces strategic risk due to a shortage of fighter pilots and limited fifth-generation fighter procurement. This paper explores an option to provide a tactical force through an unmanned aerial system without adding to the fighter pilot requirement. The Air Force cancelled the next generation of unmanned aerial systems that would provide this capability. However, the Air Force can provide tactical capability at low cost by producing a MQ-16 from the QF-16 program. Such a program will allow the Air Force to develop long-term unmanned aerial systems technology while providing near-term capability to fill the gap created by the limited procurement of fifth-generation fighters.

Filling the Airpower Vacuum

The United States Air Force (USAF) faces a complex strategic challenge: How to equip the twenty-first century force to meet ever-increasing mission sets with a decreasing budget under an ineffective acquisition program that is increasingly outstripped by the speed of technological advances? Additionally, how does the USAF overcome a fifth-generation fighter shortage and an impending fighter pilot shortage? This paper focuses on one aspect of the second question. Specifically, how can the USAF increase the tactical force to mitigate the fifth-generation fighter shortage without increasing fighter pilot requirements? To answer this question, this paper will examine the limited procurement of fifth-generation aircraft and the impending fighter pilot shortage. Additionally, it will review current Department of Defense (DoD) and USAF Unmanned Aerial Systems (UAS) guidance as well as current and near-term UAS technologies and capabilities. This paper will conclude by offering a new approach that will increase the overall capabilities of the tactical force at significantly reduced cost without further stressing pilot manning.

Limited Fifth-Generation Fighter Procurement

The bulk of the USAF tactical fleet is comprised of fourth-generation fighters such as the F-16 and F-15. The Air Force's future lies in fifth generation fighters such as the F-22 and F-35. A fifth generation fighter contains significant technological advances that increase lethality and survivability in potential hostile environments. Specifically, fifth-generation fighters incorporate stealth, active electronically scanned array (AESA) radars, highly integrated advanced avionics, and theater network capabilities.

Fifth-generation fighter requirements have been a moving target and continue to generate much debate. Some argue that there is no need for fifth-generation fighters as

a peer competitor does not exist and likely will not for some time. Additionally, they argue the cost is not justified based upon the continuing counterinsurgency fight and the need for funding and focus in that arena. Even former Defense Secretary Gates stated, "the F-22 consumes a lot of money for no tangible results."[1] Others argue that the USAF is not procuring enough fifth-generation fighters to fight tomorrow's wars. In 2008, Lieutenant General Darnell, Deputy Chief of Staff for Air, Space and Information Operations, Plans and Requirements told the Senate Armed Services air-land subcommittee that the Air Force faces a shortage of 800 jet fighters beginning in 2017.[2]

The initial Air Force requirement called for 750 F-22s. This number was reduced to 648 in 1991. A 1993 DoD bottom-up review reduced the number further to 438 aircraft. The 1997 Quadrennial Defense Review then lowered the production number to 339 F-22s to support three F-22 fighter wings.[3] Ultimately, the USAF procured only twenty-five percent of the initial requirement and stopped production after 187 F-22s. Many believe this number creates a higher level of operational risk.[4]

In order to reduce the risk of limited F-22 numbers, the Air Force is looking to the F-35. The F-35 was designed to replace the F-16 and be an economical fifth-generation fighter. Unfortunately, the F-35 followed a similar path as the F-22; it is significantly behind schedule and over budget. This has caused some to question the USAF's ability to afford the full planned procurement of F-35s[5] In fact, the USAF has postponed hundreds of F-35s over the next five years and only plans on purchasing 172 F-35s through 2017.[6] Cuts to the F-35 and delayed timelines compound the fifth-generation fighter shortage, especially over the next ten to fifteen years.

The Air Force is upgrading and extending the life of fourth-generation fighters in an attempt to fill the gap created by fifth-generation procurement shortfalls. An upgraded F-15 or F-16, called 4.5-generation, incorporates some fifth-generation capabilities such as AESA radars, but cannot provide stealth. This leads to questioning the Air Force's ability to support the National Security Strategy (NSS) in the next decade.

The NSS changed several times during the development cycle of the F-22 and F-35. The cold war mentality and need for two simultaneous theater campaigns has faded into more emphasis on counterinsurgency operations. Nevertheless, a fifth-generation fighter requirement remains and its importance is increasing with anti-access, area denial (A2/AD) scenarios. The current NSS states, "As a nation with important interests in multiple regions, our forces must be capable of deterring and defeating aggression by an opportunistic adversary in one region even when our forces are committed to a large-scale operation elsewhere."[7] In 2012, The Air Force's deputy chief of operations, plans and requirements, Lieutenant General Herbert Carlisle, stated, "You can only be in so many places. If you have to operate combat air patrols in a South China Sea scenario or some Iranian/Arabian Gulf scenario --whatever those are -- there is a quantity requirement."[8] Basic military doctrine supports this belief.

Joint Doctrine lists nine principles of war. Two of these principles become difficult to achieve with underwhelming tactical force: mass and maneuver.[9] Precision targeting changed the equation for mass with respect to ground engagement and reduced the amount of aircraft required for a joint campaign. A modern fighter can destroy multiple targets, whereas in previous eras, multiple aircraft were required to

destroy a single target. Stealth has also changed the equation for mass with respect to air engagements. A single stealth fighter can penetrate air defense systems and destroy multiple enemy aircraft and attack critical ground targets. However, stealth is not an invisibility cloak. As countries develop technologies to counter stealthy aircraft, the Air Force will not be able to rely on stealth alone and surprise will diminish, increasing the need for mass and maneuver. It will need aircraft in the sky to produce mass to overwhelm the enemy. Additionally, increased speed and range have added to maneuver. However, it is difficult to execute tactical maneuvers in relation to the enemy with limited aircraft. While the Air Force has not defined a specific fifth generation fighter requirement, it appears that the Air Force will fall short of its needs, especially in the next decade, as F-35 procurement slips farther to the right.

Fighter Pilot Shortage

To manage rated manning, the USAF utilizes redline/blueline charts. These charts are produced semi-annually and show expected requirements compared to projected inventory. The redline is requirements and the blueline is inventory for Lieutenant Colonels and below.[10] Thus, the redline above the blueline indicates a projected shortage of pilots. Figure 1, Fighter Pilot Redline/Blueline shows an expected shortage of approximately one thousand active duty fighter pilots in the coming years.[11] The fighter pilot shortage was a top issue at a recent CORONA conference, a meeting of the top Air Force generals to address long-term Air Force issues. Specifically, Air Force leadership tasked the Air Force Director of Operations (AF/A3O) to scope the issue and provide possible solutions.

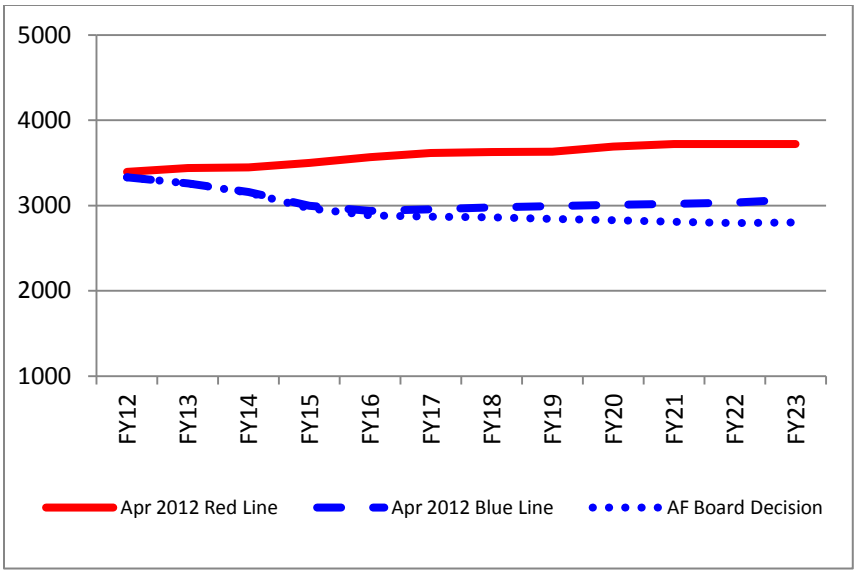


Figure 1. Fighter Pilot Redline/Blueline

AF/A3O has proposed several options to solve the shortage. Every option has significant ramifications as the Air Force has limited ability to increase supply. The amount of training aircraft in the USAF inventory has steadily decreased over time from approximately 2,700 in the 1970s, to 1,800 in the 1980s, and finally to the present day level of 1,500[12]. During this decline, aircraft have become more complex adding to the amount of time required to train a mission-ready fighter pilot. Additionally, the USAF closed several training bases as part of the Base Closure and Realignment. Due to current and expected fiscal constraints and extended training timelines, it is unlikely the USAF can increase supply any time soon.

The Air Force's only viable option is to decrease demand by cutting jobs outside of the operational cockpit, especially on the rated staff. But, the Air Force leadership considers it important to have fighter pilots on the staff, as well as instructors in pilot training, in test and evaluation, and as air liaison officers to the Army; all while continuing their professional military education.[13] Several Major Commands have non-

concurred on courses of action provided by AF/A3O and at the moment, no solution seems palatable.

In 2009, the Air Force created a separate career field for UAS pilots to reduce the burden on the fighter community and the pilot training pipeline. The Air Force is now training UAS pilots in a separate pipeline than traditional pilots. However, the shortage indicated in Figure 1. Fighter Pilot Redline/Blueline already includes this change. Thus, the Air Force expects to be one thousand fighter pilots short even with the separate UAS career field.

To tackle these challenges, the USAF is looking to autonomous UASs with fifth-generation fighter capabilities. An autonomous UAS reduces manpower requirements versus current remotely piloted aircraft. Additionally, a UAS with fifth-generation fighter capabilities can fill the shortage of fifth-generation aircraft. Overall, a new UAS with fifth-generation fighter capabilities would appear to be a feasible solution.

Department of Defense (DoD) and USAF UAS Guidance

The Department of Defense and USAF consider unmanned systems a key enabler in the current and future force structure. As such, the DoD and USAF published guidance and roadmaps for unmanned systems. This guidance includes unmanned systems for every domain and commonality for joint operations. In order to achieve commonality, the DoD provided guidelines for future UAS procurement and the USAF further refined UAS objectives for future systems. One of the main themes throughout DoD and USAF documents is autonomy.

UAS Autonomy

The USAF Chief Scientist calls for moving from manned to remotely piloted aircraft and from control to autonomy over the next twenty years.[14] By moving to

systems that are more autonomous the DoD and USAF will capitalize on increased manpower efficiencies, reduce communications risks, reduce risk to life, and ensure seamless teaming with manned systems. The DoD defines four levels of automation (reference Table 1) as a common reference for the services.

Table 1. Four Levels of Autonomy[15]

Level	Name	Description
1	Human Operated	A human operator makes all decisions. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	The vehicle can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	The system can perform a wide variety of activities when given top-level permissions or direction by a human. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or change the goals, although in practice there may be significant time delays before human intervention occurs.

Today's unmanned systems require a high degree of human interaction.[16] For example, two pilots and a sensor operator in a ground control station operate a single MQ-9. When the MQ-9 is forward deployed, a local ground control station provides control for takeoff and landing, adding to the manpower requirement. Several years ago, to increase the MQ-1 and MQ-9 combat air patrols (CAPs) to 65 in support of combatant commander's needs, the USAF estimated a total force requirement of 1,750 pilots.[17] The manpower requirements are staggering for a system that, while performing outstandingly, can only operate in a non-contested environment. The goal of the DoD is to reduce this manpower burden through automation.[18]

Current UAS command and control rely on a long communications chain utilizing satellite communications (SATCOM). The forward deployed ground station utilizes direct line of sight signals for takeoff and landing. The U.S. based ground station

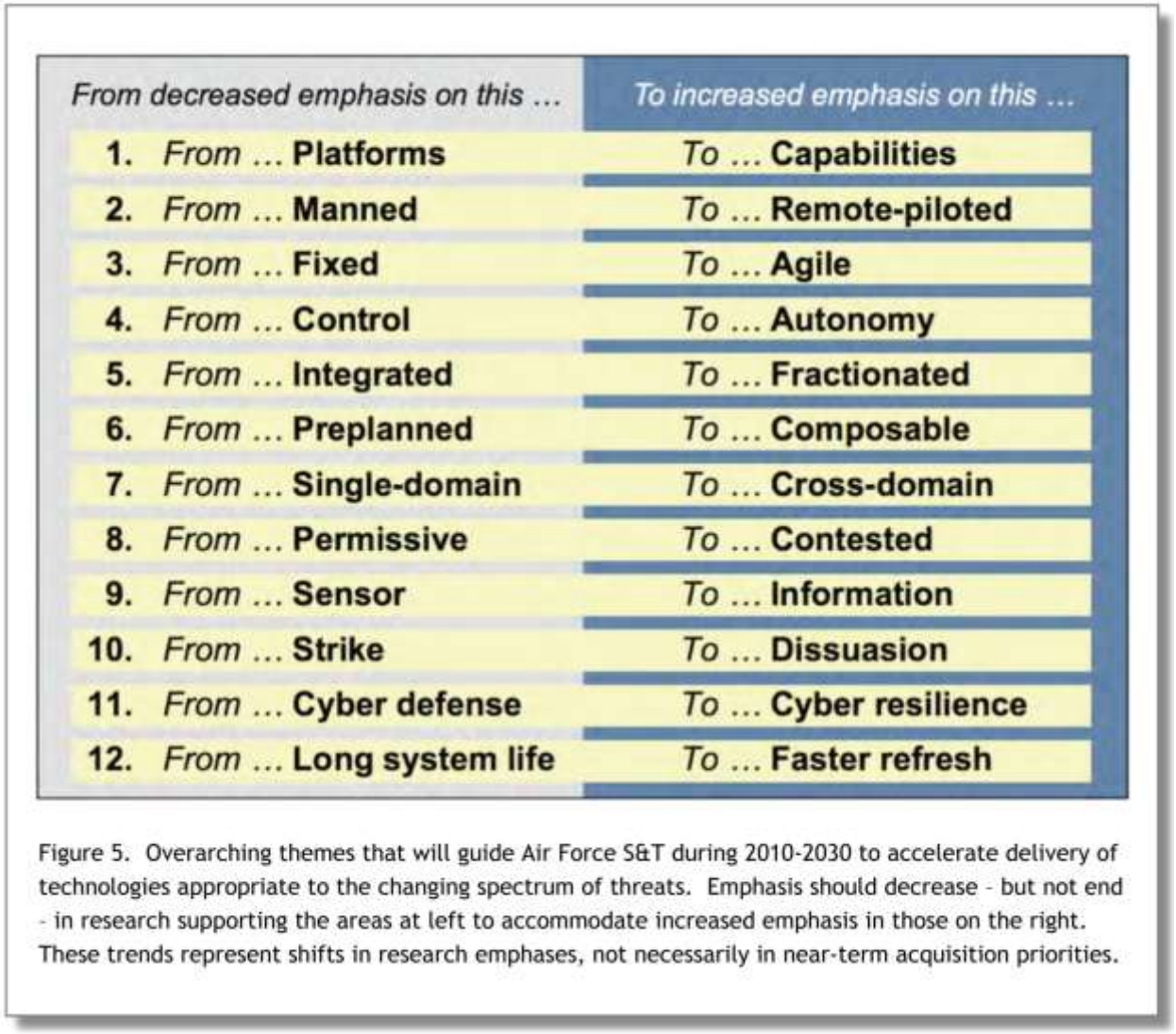
utilizes SATCOM to communicate across the globe with the MQ-9 to execute the primary mission. Additionally, the U.S. ground station must be able to communicate with the forward deployed ground station for handoff. This extensive communications network is costly in manpower and infrastructure and relies heavily on high-speed, expensive, limited-bandwidth SATCOM. More importantly, such a long communications chain is extremely susceptible to a number of threats.[19]

The UAS of today does not integrate well with manned aircraft. The MQ-9 is the most capable tactical UAS, but is well below the performance of a modern fighter and often has very limited communication with airborne fighters. The result is limited integration. Currently, operators divide tasks and geographically separate manned and unmanned systems to overcome communications issues and avoid collisions. In an effort to improve integration, the DoD is seeking to acquire UASs capable of teaming directly with manned aircraft.[20] Specifically, the USAF is pursuing two near-term concepts called swarming and loyal wingman. This technology will allow partially autonomous UASs to operate together in a swarm or fly with a manned aircraft as a "loyal wingman."[21]

Current USAF UAS development

The USAF is shifting its research and development emphasis to account for advances in technology and the expected realities of twenty-first century warfare. The pace of technological advances risks making weapon systems obsolete by the time they are fielded. Additionally, technology allows modern platforms to perform multiple missions across multiple domains. In order to meet these challenges, the U.S. Air Force Chief Scientist published new emphasis for Air Force research and development in *Technology Horizons* (see Figure 2. USAF Research Emphasis).[22] Of note, the term

"integrated" on the left side of Figure 2 does not refer to manned, unmanned integration, but to systems integration. The USAFs long-term objective is to procure a tactical UAS that falls within these guidelines.



From decreased emphasis on this …	To increased emphasis on this …
1. From … Platforms	To … Capabilities
2. From … Manned	To … Remote-piloted
3. From … Fixed	To … Agile
4. From … Control	To … Autonomy
5. From … Integrated	To … Fractionated
6. From … Preplanned	To … Composable
7. From … Single-domain	To … Cross-domain
8. From … Permissive	To … Contested
9. From … Sensor	To … Information
10. From … Strike	To … Dissuasion
11. From … Cyber defense	To … Cyber resilience
12. From … Long system life	To … Faster refresh

Figure 5. Overarching themes that will guide Air Force S&T during 2010-2030 to accelerate delivery of technologies appropriate to the changing spectrum of threats. Emphasis should decrease - but not end - in research supporting the areas at left to accommodate increased emphasis in those on the right. These trends represent shifts in research emphases, not necessarily in near-term acquisition priorities.

Figure 2. USAF Research Emphasis[23]

The USAF roadmap is outlined in the *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047.* The goal is a medium sized UAS (MQ-Mc) by 2020 with enhanced autonomy, modular open architecture, and networked systems with a

wide range of mission capabilities (see Figure 3. Medium System Evolution).[24] The roadmap builds upon lessons learned from the MQ-1 and MQ-9 with incremental steps to develop technology required for the MQ-Mc. The interim UASs (MQ-X, MQ-Ma, and MQ-Mb) provide a near-term capability while developing parallel technologies. The ultimate goal is a "gold-plated" system that accomplishes a wide range of missions from a singular modular platform.[25]

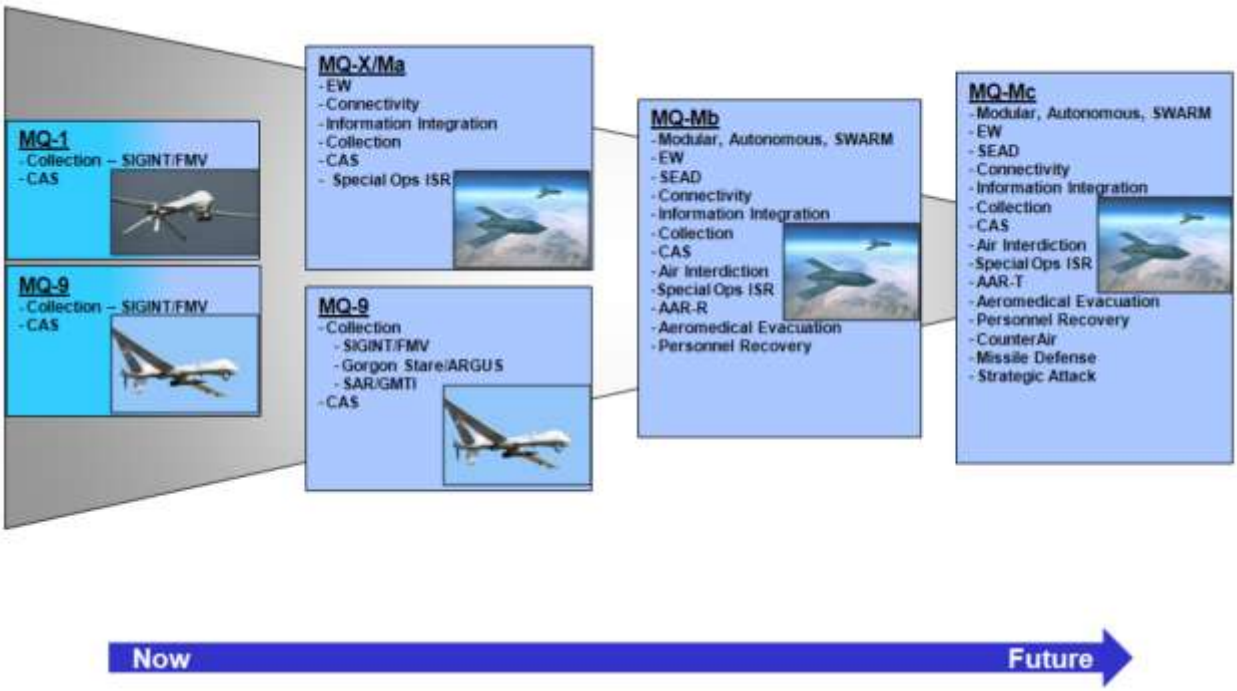


Figure 3. Medium System Evolution[26]

The Air Force decided in February 2012 to cease development of the MQ-X.[27] The cancellation is likely due to several factors to include tightening budgets, increased acquisition costs, and the inability to strike a balance between desired capabilities and cost. This leaves future medium-sized UAS development at a crossroads. The USAF has decided to take a "wait and see" approach and observe the outcome of the U.S.

Navy's Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) program before deciding on future UAS development.[28]

Near-Term UAS Technology

Current USAF UASs are at level 1 automation requiring a human operator to make all decisions. The MQ-1 and MQ-9 touch on level 2 with some automation in the event of lost link, but do not cross the threshold where many functions are delegated to the UAS. Level 2 automation is achievable as demonstrated by modern autopilot systems. A commercial airline pilot can program the entire flight profile into a modern autopilot and simply monitor the aircraft. Loyal wingman operations require level 3 automation (human supervised) and swarming requires level 4 automation (fully autonomous). Level 3 automation appears promising as a near-term technology while level 4 automation is in its infancy for UASs.

The research world is actively testing level 3 automation. The U.S. Army is pursuing manned-unmanned systems integration capability (MUSIC) to control several UASs from a single control station.[29] A manned helicopter could also control the UASs and receive the UAS sensor video. In coordination with MUSIC, Kutta Technologies formally launched a manned/unmanned teaming kit to allow Level 3+ control of a UAS while still flying his or her own aircraft[30]. Additionally, Utah State University has tested two small UASs flying in formation as a flight lead and wingman.[31] These are a few of many examples of level 3 automation research and development projects.

Manned-unmanned teaming and loyal wingman operations require level 3 automation. Several challenges exist for a UAS to fly formation with a manned aircraft. The first challenge is for the UAS to fly formation while avoiding the manned aircraft.

The second challenge is for the UAS to avoid other aircraft. The Utah State University test demonstrated the ability to fly formation and avoid the lead aircraft.

The Utah State University test utilized a leader-follower strategy. The Utah State team utilized a mature, open-source autopilot software, Paparazzi, that includes basic functions to accommodate multiple UAV formation flights.[32] Simulation has tested multiple formation schemes: (1) Two UAVs: leader-follower formation; (2) Three UAVs: leader-followers triangle and string formation; (3) Four UAVs: square formation; (4) Four UAVs: tetrahedron formation (One leader above with three followers beneath); (5) Five UAVs: string and pyramid formation.[33] The Utah State team successfully flew two and three UAV flight formations.[34] The lead aircraft flew a pre-programmed route while the follower aircraft tracked the lead aircraft and maintained a formation scheme.[35] However, flying three small scale UASs in formation in a benign environment is far from flying a fighter type UAS into a hostile environment teamed with a manned aircraft.

A New Approach

As discussed, the Air Force is pursuing multiple, parallel technologies to design the MQ-M. The Air Force chose to take incremental steps in developing the MQ-M by first developing interim UASs, but the Air Force cancelled the first UAS, the MQ-X. With no interim UAS development, the USAF will not have near-term tactical UAS capability beyond the MQ-1/9 and risks losing the tactical advantage in the anti-access, area denial (A2/AD) environment with F-35 procurement delays. However, another solution may exist. The Air Force can develop an F-16 UAS from the QF-16 program. For the purpose of this paper the F-16 UAS will be designated the MQ-16. The objective of the MQ-16 is to develop some of the MQ-M technologies while providing a cost effective near-term capability. Additionally, the MQ-16 will offset the fifth-generation fighter

procurement gap without increasing fighter pilot requirements. The keys to such a concept are simplicity and low cost.

Scenarios and capabilities

One of the most difficult challenges of weapons systems procurement is anticipating the threat to determine requirements. The scenarios requiring support vary widely from violent, well-armed, low-tech, non-state actors to rising, near-peer, state actors. Many of today's scenarios will carry forward in the short term while future conflicts remain difficult to predict. Nonetheless, over the next ten years, the probability of large-scale global war is unlikely, with limited engagement being most likely. The U.S. will fight non-state enemies through police action and special operations with limited kinetic strikes. State level scenarios will likely also be limited, but if they occur, would likely require periods of overwhelming conventional air power. These state level scenarios range from a low-tech, large conventional army to a more sophisticated enemy protected by a robust integrated air defense system (IADS).

A low-intensity conflict, such as counter insurgency, requires precision strike and persistence. In this scenario, air superiority is usually a given, allowing freedom of maneuver with low risk for any platform. In order to prosecute a target when it appears, aircraft must either remain on station for long periods or be readily available. The MQ-1/9 provides persistence through long loiter times. Fighters provide persistence through aerial refueling and speed to cover greater distances. Precision strike is required to destroy soft targets, such as buildings and vehicles, while reducing collateral damage. Any range of platforms can provide these required capabilities.

A high-intensity conflict, such as an A2/AD scenario, requires precision strike, force extension, and survivability. Aircraft must gain air superiority and be able to

survive modern surface-to-air missiles (SAM) systems and anti-aircraft artillery (AAA) within an IADS. Additionally, aircraft must have precision strike capability with larger weapons to defeat hardened targets, such as bunkers. The MQ-1 and MQ-9 are not considered survivable in A2/AD scenarios and cannot carry weapons larger than five hundred pounds. Overall, the MQ-1/9 has a low probability of both success and survival in a high-intensity conflict. The F-35 and F-22 have a high probability of success and high survivability, assuming enough fighters are available.

It is difficult to quantify risk when comparing manned and unmanned aircraft. How does one measure the risk between the loss of life and mission failure? Significant loss of life is high risk, as is the loss of a large number of unmanned platforms with no return of effectiveness. Ultimately, the USAF accepts risk to win America's wars and for the near future must accept the risk to life for high-intensity conflicts. Risk must balance the loss of life with the loss of large numbers of essential unmanned systems. By defining risk as such, one can compare risk versus success for platforms in a high-intensity A2/AD scenario. Figure 4. Risk versus Success in A2/AD provides a comparison. This chart is very simplistic and an entire study would be required to quantify these assertions. The point of the chart is to demonstrate that without a fifth-generation capable UAS, the next best option to supplement the limited number of fifth-generation fighters is a 4.5-generation fighter followed closely by a fourth-generation UAS. With the expected shortage of fighter pilots, a fourth-generation UAS provides tactical flexibility with reasonable mission success at an acceptable level of risk. The difficulty is determining what capabilities a fourth-generation UAS requires to contribute to mission success while managing losses.

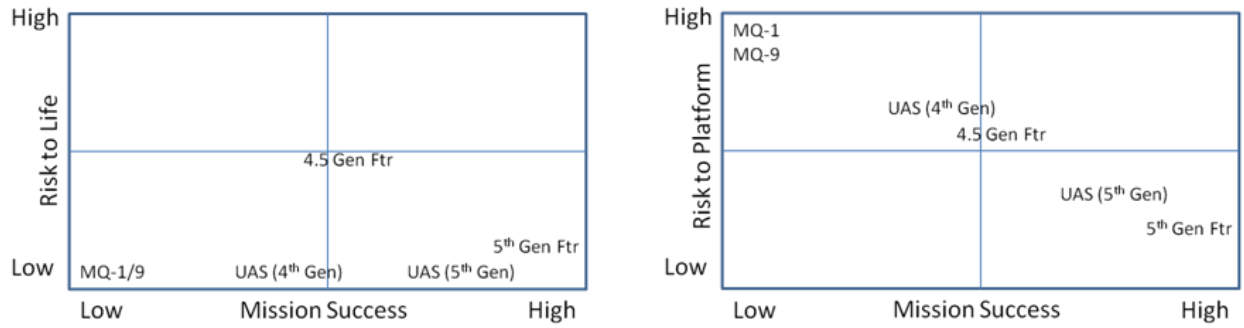


Figure 4. Risk versus Success in A2/AD

The USAF can utilize a UAS with fourth-generation capability in both low-intensity and high-intensity scenarios. For ease of terminology, this paper will refer to a UAS with fourth-generation fighter capabilities as a fourth-generation UAS. One can glean from experiences with the MQ-1/9 and fourth-generation fighters that a fourth-generation UAS can succeed in a low-intensity conflict. The difficulty arises in determining capability requirements for a high-intensity conflict. The Air Force has determined the best solution short of fifth-generation fighters is upgraded fourth-generation fighters. Therefore, a fourth-generation UAS can fill the fifth-generation gap in a similar fashion with slightly less capability but at lower risk. As such, a list of six capabilities will provide a fourth-generation UAS with enough capability to employ across a wide range of conflicts with an acceptable level of survivability in an A2/AD scenario: (1) loyal wingman autonomy, (2) flight lead designated precision weapons employment, (3) aerial refueling, (4) short, secure communications link, (5) fourth-generation fighter aerodynamic performance, (6) electronic attack and protection.

QF-16 modified as MQ-16

The F-16 is a fourth-generation fighter with precision attack, aerial refueling, and electronic attack and protection capabilities. The F-35 is replacing the F-16, which will

slowly be phased out and sent to long-term storage with previously retired F-16s. The USAF is already converting a portion of these retired F-16s in storage into a UAS, the QF-16.

The QF-16 will replace the QF-4 as the Air Force's Air Superiority Target (AST), or target drone. Pilots fly the QF-16 either manned or unmanned. When flown unmanned, pilots control the QF-16 by direct line-of-site communications. An unmanned QF-16 is able to fly supersonic, utilize after-burner, conduct high-G maneuvers, and employ advanced electronic attack and electronic protection.[36] In short, the QF-16 will perform at the level of a fourth-generation fighter without weapons employment capability. The QF-16 does not possess weapons employment capability, as it is not required of a target drone. The USAF can easily modify the QF-16 to employ weapons, as this capability is inherent in the F-16. Thus, the QF-16 already meets several of the proposed capabilities listed for a tactical UAS.

The QF-16 fully meets two of the six capabilities: fourth-generation fighter aerodynamic performance and electronic attack and protection. The QF-16 also partially meets two of the six capabilities: flight lead designated precision weapons employment and aerial refueling. While the USAF can easily modify the QF-16 for weapons employment, the flight lead must possess control of munitions. The QF-16 has the same refueling system as the F-16, but does not possess the ability to fly formation with a tanker. In addition, the QF-16 does not possess loyal wingman capabilities. However, the QF-16 could utilize existing short, secure link architectures for loyal wingman operations. Therefore, four technical challenges exist to meet the proposed capabilities: loyal wingman operations, flight lead designated precision

weapons employment, autonomous aerial refueling capability, and control through short, secure communications links. Additionally, survivability, and integration with stealth aircraft are important and will be discussed.

Loyal Wingman

Loyal Wingman automation is the ability of a UAS to fly formation with another designated flight lead aircraft as discussed previously. Again, various research laboratories and universities with successful test demonstrations are earnestly pursuing this technology. These demonstrations show the feasibility of loyal wingman operations at a basic level. The USAF needs to expand this technology to ensure aircraft separation and robust maneuvering. Additionally, a secure communications link between the manned aircraft and UAS must exist. Currently, operational F-16s utilize Link-16 to share information and the F-35 utilizes Multifunction Advanced Data Link (MADL). Theoretically, both Link-16 and MADL provide enough information to allow a UAS to execute loyal wingman operations. This concept needs to be fully designed and tested.

A loyal wingman MQ-16 must avoid the manned aircraft. Various research and development tests show the loyal wingman can easily avoid the manned aircraft in a benign environment. However, the dynamics become more complicated if the manned aircraft or MQ-16 flies defensive or offensive maneuvers. The USAF must properly develop and test such maneuvering.

A loyal wingman MQ-16 must also avoid other aircraft. This consideration changes based upon the airspace structure and flight rules. Developers can more easily design a loyal wingman to avoid other aircraft on the link architecture flying in

combat or in restricted areas. However, avoiding civilian traffic in congested peacetime airspace is a different matter. The solution may be to have the MQ-16 fly within standard formation of the manned aircraft with Federal Aviation Administration (FAA) agreements. Designing the MQ-16 with a traffic collision avoidance system may provide another solution. The USAF must work with the FAA and developers in determining the best way for the MQ-16 to avoid other aircraft or fly in special use airspace without adding significant cost to the program.

Flight Lead Designated Precision Weapons Employment

The delivery of a modern weapon is much simpler than in previous eras. Many of today's air-to-ground weapons simply require the operator to enter accurate coordinates into the weapon, position the aircraft into a large employment window, and release the weapon. Even those weapons that do not utilize GPS for guidance, such as laser-guided bombs, are easily released onto accurate coordinates while the host aircraft or an off-board laser provides terminal guidance. Overall, the precision weapons carried by a MQ-16 are simple to employ as they only require accurate coordinates and for the MQ-16 to be positioned in a release window. A manned aircraft can easily provide these coordinates to the MQ-16 through Link-16 or MADL.

The air-to-air capability of the MQ-16 will be more limited, but an inherent capability will exist. The primary benefit of the MQ-16 carrying air-to-air ordnance is to provide more firepower to the F-35, F-22, or manned 4.5-generation fighter. The manned fighter would provide the sensor to detect and target enemy aircraft, but have the option to utilize air-to-air missiles from the MQ-16. There are several factors to consider, especially with the expanded aerodynamic envelope of the F-22. For a detailed discussion, reference Lieutenant Colonel Thomas J. Browning's research

project, *Cooperative Engagement: Concept For a Near Term Air-To-Air Unmanned Combat Aircraft System.*[37] One of the main concerns, and sometimes the most difficult task for air-to-air or air-to-ground weapons employment, is target identification.

There is valid concern in the Department of Defense (DoD) on target identification and the risk of fratricide with autonomous weapons systems. The ability to determine friend or foe and make the decision to employ lethal force is complex and made through various automated systems such as identification friend or foe (IFF), situational awareness, and/or visually discerning a target. Ultimately, a human makes the final decision based upon any or all of these systems and methods. A manned fighter would be the release authority for a MQ-16. The MQ-16 is simply providing additional weapons for the manned fighter and would have no autonomous weapons release authority. Additionally, there must be a method to verify the target that the MQ-16 will attack.

The weapons release logic for the MQ-16 must include verification of the target to ensure the MQ-16 meets JP 3-09.3 requirements for close air support. JP 3-09.3 requires read back of coordinates when dropping a weapon solely on the coordinates provided[38]. Since the MQ-16 is simply dropping on coordinates for all air-to-ground weapons delivery, it must be able to transmit the coordinates loaded in its system back to the manned aircraft. The manned aircraft can then provide release authority. While this sounds complex, such a capability already exists in Link-16 and would simply need to be incorporated into the software of the MQ-16 and host aircraft.

Aerial Refueling

The MQ-16 must possess an aerial refueling capability in order to be an effective tactical UAS. The Air Force and Navy recognize the importance of force extension for future UASs. Moreover, force extension is a pre-requisite for most current tactical Air Force missions. Northrop Grumman in coordination with the Navy is testing the X-47B with plans to demonstrate autonomous aerial refueling with Navy "probe and drogue" and Air Force "boom-receptacle" systems in 2014.[39] Additionally, Northrop Grumman and DARPA demonstrated an initial capability with two NASA Global Hawk unmanned aircraft. The initial test flights in early 2012 achieved many milestones on the road to complete UAS aerial refueling capability. The most significant milestone related to this paper was the aircraft rendezvous and two and a half hours of autonomous formation flight, with the majority of the time within 100 feet (or one wingspan).[40] This flight demonstrated the loyal wingman concept and the ability of a UAS to fly autonomously in close formation for aerial refueling. This capability appears to be achievable in the near term.

Short, Secure Communications Link

Current UASs require long communications architecture through SATCOM. This places a UAS at risk as near-peer competitors develop technologies to contest U.S. space dominance. Additionally, A UAS flying over enemy territory will be susceptible to jamming. The solution is full autonomy or short, secure communications links in contested environments.

The MQ-16 would utilize Link-16 or MADL to fly loyal wingman operations. Link-16 and MADL are both secure and operate over short distances. The distance between

the manned aircraft and loyal wingman is relatively short, measured in thousands of feet or single digit miles. Such short distances are much more difficult to jam. The USAF must develop the technology to allow the MQ-16 to fly loyal wingman operations through Link-16 or MADL. The key is simplicity; the manned aircraft is not piloting the MQ-16 and the workload is no higher than with a normal wingman in formation. Instead, the MQ-16 is utilizing link information to maintain formation, and then engage a target when tasked. The intent is not to design new link architecture, but leverage the existing architecture.

Survivability

Survivability is a pre-requisite for a modern fighter and the MQ-16 must possess reasonable survivability in a hostile environment. Current UASs such as the MQ-1 and MQ-9 are great platforms for counter-insurgency operations, but are not survivable without air dominance. The MQ-1 and MQ-9 are expected to have a very low survival rate in an integrated air defense system against AAA, SAMs and enemy fighters. The MQ-16 possesses similar survivability as an F-16 with the main difference being the ability to fly a threat reaction maneuver. Engineers can likely design the MQ-16 to fly threat reaction maneuvers, but loyal wingman responsibilities may override threat reaction maneuvering. This will likely reduce the MQ-16's survivability in comparison to a manned F-16. The advantage that a MQ-16 will have over current UASs is speed, maneuverability, threat detection, electronic attack, and electronic protection. Overall, the concept should be to accept a greater risk of loss for the unmanned MQ-16 vice spending countless hours and money to create a MQ-16 able to threat react like a manned fighter and therefore difficult to control as a loyal wingman.

Integration with Stealth

Integrating a MQ-16 with a F-35 strike package defeats one of the purposes of stealth -- surprise. So, why pursue a MQ-16? As discussed earlier, the USAF significantly reduced fifth-generation fighter procurement due to budget cuts and increased program costs. This limits mass and maneuver. The MQ-16 provides flexibility and mass when required. Our tacticians will determine when and where to utilize mass and use the MQ-16. If a package requires only stealth, the MQ-16 may not be utilized. On the other hand, if the package requires mass and stealth, planners can separate the MQ-16 from stealth assets to provide both. Additionally, fourth-generation and 4.5-generation fighters will be in the Air Force inventory for at least another decade and can be the flight lead for a loyal wingman MQ-16. Ultimately, the MQ-16 provides flexibility that smart tacticians will utilize for multiple missions across varying levels of risk.

What is not required

The purpose of utilizing the MQ-16 versus pursuing a new UAS is cost. The Air Force cancelled the MQ-X and placed the MQ-M on hold due to budget constraints and the cost of research and development of multiple new technologies. The MQ-16 utilizes an existing airframe and only requires the development of a few technologies that have already been initially tested and proven promising. The MQ-16 does not need to possess all the capabilities of an F-16 or an F-35; it will utilize information from the host aircraft to fly formation and employ weapons. Therefore it will not need some of the more expensive items found in or on a mission capable F-16. Specifically, the MQ-16 will not require a radar, targeting pod, HTS pod, gun, or AIM-9. The most expensive item it may carry would be an ECM pod for employment in an IADS. The intent is to

keep costs low and develop longer-term technology while providing near-term capability.

The MQ-16 has the potential to be relatively low cost. Producing a new UAS is significantly more expensive than an MQ-16 as retired F-16s provide the MQ-16 airframe. The QF-16 provides a starting point for expected MQ-16 cost and Table 2 provides some perspective. There is significant savings between the cost of the QF-16 and the MQ-9 and a monumental difference in cost compared to fifth-generation fighters. Ultimately, the final cost of the MQ-16 will depend on research and development of the technologies discussed, desired capabilities, and compatibility with existing support architecture. The benefit of the MQ-16 is the logistics support in place for the F-16, which has many years of service remaining. Ultimately, if properly developed, an MQ-16 program can provide tactical capability at a relatively low cost.

Table 2. Platform Cost Comparison[41]

Platform	Cost (Millions)
QF-16	$4.2
MQ-1	$4.03
MQ-9	$36.8
F-35	$237.7
F-22	$412.0

Recommendation

Defeating a modern integrated air defense system requires fifth-generation fighters and this requirement becomes more critical with each passing year. The Air Force procured significantly less F-22s than planned and is slipping and reducing procurement of the F-35. The result is increased risk and the inability to produce mass

and maneuver. To compensate, the Air Force is extending the service life and upgrading fourth-generation fighters with some fifth-generation capability. Additionally, the USAF decided to pursue the MQ-M, a fifth-generation capable UAS. Subsequently, the Air Force cancelled the MQ-X and put the MQ-M on indefinite hold. The result is increased risk to mission success and manned fourth-generation and 4.5-generation fighters in A2/AD conflicts. The Air Force should pursue the MQ-16 to offset these risks. The MQ-16 can provide mass and maneuver for the tactical force while reducing overall risk without increasing fighter pilot requirements.

Reducing the number of fighter pilot requirements outside the cockpit, such as on the rated staff, comes with significant long-term ramifications. Obviously, the fighting force is critical to the nation's defense. As such, senior leaders are unwilling to allow cockpits to go unfilled for the sake of non-flying positions. The Air Force cannot easily increase supply due to the long supply chain required to produce a fighter pilot. Budget cuts and training wing closures are compounding this supply issue. The Air Force may get to a point that it cannot fill cockpits and balance non-flying rated positions. By developing the MQ-16, the USAF will have an alternative to leaving cockpits unfilled. A manned fourth-generation fighter is more capable than an MQ-16 and should be the Air Force's priority. However, no solution currently exists if the Air Force cannot fill fighter cockpits. The MQ-16 provides this buffer.

Developing the MQ-16 as a tactical UAS will allow the Air Force to develop several technologies required by the MQ-M and do so more cost effectively than producing new interim platforms. Specifically, the Air Force will gain experience and develop loyal wingman technology, autonomous aerial refueling, shortened UAS

communication links, and flight lead designated precision weapons employment. These technological spin-offs will provide the Air Force capability required in the long-term at a reasonable cost while providing a near-term capability and provide valuable experience in manned-unmanned teaming.

The MQ-16 will also directly benefit the QF-16 program and can share procurement costs. As F-35 and MQ-M numbers increase, instead of retiring the MQ-16, it can become the QF-16 at little to no additional cost. The Air Force will still need ASTs for many years to come and the MQ-16 can be the primary means to gain long term ASTs. As part of the long-term AST program, the Air Force can produce MQ-16s from retired or retiring F-16s, and then when the USAF no longer needs the MQ-16, easily convert it into the QF-16.

Conclusion

The Air Force faces some significant challenges over the next decade with the limited procurement of fifth-generation fighters and the shortage of fighter pilots. The Air Force has cancelled the MQ-X and indefinitely delayed the MQ-M, which would have helped reduce the impact of these two issues. Nevertheless, another solution exists - the MQ-16. The MQ-16 will provide a semi-autonomous, more survivable UAS than currently exists without adding to the fighter pilot shortage. Additionally, if the Air Force finds itself unable to fill fighter cockpits, the MQ-16 will fill the capacity gap to meet tactical requirements. The MQ-16 provides an option that provides mass, maneuver, and flexibility to combatant commanders across the conflict spectrum without risking significant loss of life in an A2/AD scenario. The Air Force should pursue the MQ-16 -- it is a viable option to tackle two of the Air Force's strategic challenges.

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